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Comparison of Slips and Pulling Forces on Worn and New Tyres

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The slip, the resistance to rolling and pulling force are interconnected. The influence of tyre wear on the tractor pulling force and slip on three different grounds was observed. The tangential force was measured by dynamometers fixed to tractor driving half-axle. The pulling force on the pulling rods was measured by dynamometer fixed to the pulling force. The tractor was braked under control by the vehicle in which the measuring instruments were placed. The slip was measured by means of the fifth wheel. The measurements were carried out on the AGT 835 T tractor with diagonal tyres of Ruma Guma make 7.5 – 16. The tyre wear amounted to 46.7 %. In the case of tyre wear the differences are rather small or even do not occur. When using new tyres a 3 to 5 % smaller slip was observed during plowing. On the asphalt greater tangential force was observed when using worn tyres. On the grassland where maximum pulling forces were observed there were no differences between worn and new tyres.

Usporedba klizanja i vučne sile na trošnim i novim gumama

Izvornoznanstveni članak

Klizanje, otpor vožnje i vučna sila međusobno su povezani. Promatrali smo utjecaj trošenja pneumatika na vučnu silu traktora i klizanje na tri različite vrste tla. Tangencijalnu silu smo izmjerili dinamometrima, koji su bili pričvršćeni na pogonskoj poluosi traktora. Dinamometrima koji su bili montirani na vučnu silu, mjerili smo vučnu silu na vučnim polugama. Vozilo, u kojem su bili namješteni instrumenti za mjerenje, u kontroliranom je stanju kočilo traktor. Klizanje smo mjerili pomoću petog kotača. Mjerenja smo izvodili na traktoru AGT 835 T sa dijagonalnim pneumatikama tipa Ruma Guma 7.5 – 16. Trošenje pneumatika iznosilo je 46.7 %. Pri trošenju pneumatika razlike su neznatne ili ih uopće nema. Upotrebljavajući nove pneumatike prilikom oranja, opazili smo 3 – 5 % manje klizanje. Prilikom upotrebe novih pneumatika na asfaltu smo opazili veću tangencijalnu silu. Na travnatoj površini, gdje smo opazili maksimalnu vučnu silu, nije bilo razlike među trošnim i novim pneumatikama.

1. Introduction

The tyres are part of wheels and are one of the basic components for transmission of driving power from driving half-axles to ground and from there to the tractor [1]. They are also important for braking and steering of the tractor [2]. In the beginning the tractors equipped with steel wheels. About 1920 tests for replacement of steel wheels by tyres started in Europe. In 1932 Goodyear introduced production of tyres for tractors. The first tractor having rubber tyres was Allis Chalmers. Since the development of tyres until their wide utilization only a few years elapsed. Introduction of tyres was one of the most important inventions in the development of the tractor during whole history [3].

2. Definition of research problem

The tractor driving tyres are subject to wear [4]. The height of tyre ribs wears out the most [5]. The paper is aimed at determining the reduction of the pulling force and the increase of the slip on different grounds. We measured the pulling force, the slip and the resistance to rolling on new and worn tyres. Measuring was effected on three different grounds, i.e., during plowing of stubble field, during breaking on the grassland and asphalt.

3. Measurements

The measurements were carried out on the AGT 835 T tractor of rigid construction with mechanical transmission. The diagonal tyres of Ruma Guma make 7.5 – 16 were

Symbols/Oznake

N	- carbon dioxide ugljični dioksid
km/h	- oxygen - kisik
s	- hydrogen - vodik
η_f	- hydrogen sulfide - vodikov sulfid

Indices/Indeksi

º	- degree - stupanj

used for measurements. These are standard tyres with average rib height of 24.3 mm. The ribs were ground to 11.4 mm so that wear was 46.7 %. The measurements were performed during controlled breaking on the asphalt and grassland and during plowing of stubble field with a two-furrow one-side plough. The tangential force, the pulling force on the pulling rods and the slip of each wheel separately were measured. First the measurements with new tyres and then with worn tyres were performed [6]. Also the resistance to rolling with non-loaded tractor was measured.

4. Comparison of slips and forces between worn and new tyres during plowing of stubble field

Table 1 shows the comparison of average force and average speed for new and worn tyres [7].

Table 1. Average force and average speed for worn and new tyres

Tablica 1. Prosječna sila i prosječna brzina za trošne i nove pneumatike

	Average force / Prosječna sila, N	Average speed / Prosječna brzina, km/h
Worn tyres / Trošne pneumatike	1295	4.90
New tyres / Nove pneumatike	1792	4.94

From each repetition the average slips and tangential forces were calculated; in total there were 5 repetitions (Figure 1).

Figure 2 shows the dependence of the slip on the force and the two linear straight lines for worn and new tyres [8].

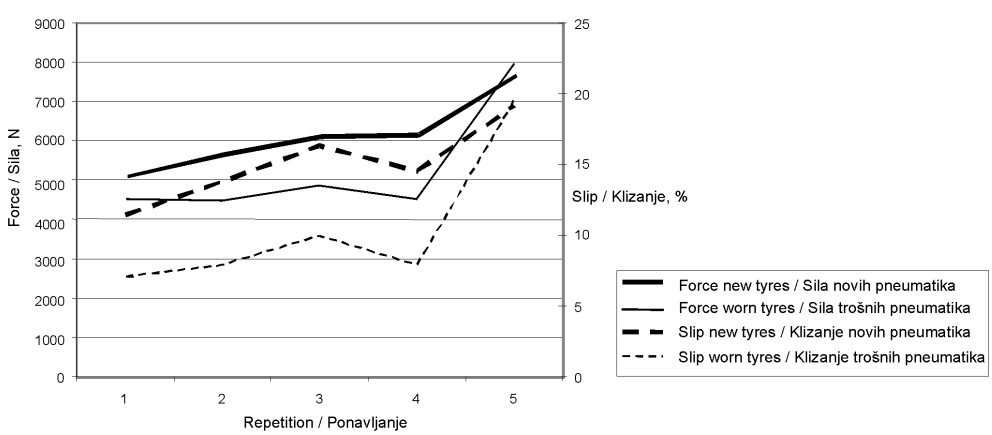

Figure 1. Average slips and tangential forces

Slika 1. Prosječno proklizavanje i tangencijalne sile

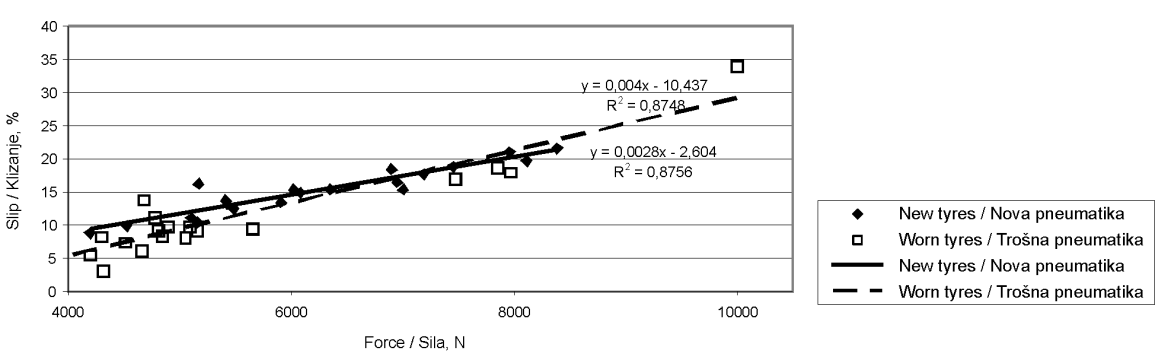

Figure 2. Dependence of slip on the force and linear straight lines for worn and new tyres

Slika 2. Ovisnost kliženja od sile i linearnih pravaca kod trošnih i novih pneumatika

Figure 3 shows the comparison of slips and tangential forces (worn and new tyres), linear average.

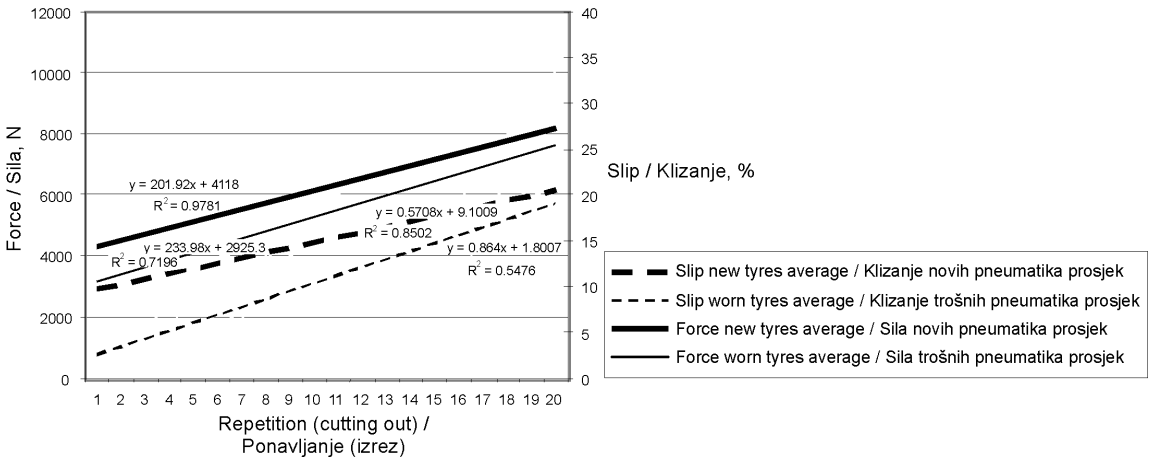

Figure 3. Comparison of slips and tangential forces (worn and new tyres), linear average

Slika 3. Usporedba kliženja i tangencijalnih sila (trošne i nove pneumatike), linearan prosjek

Figure 4 shows the resistance to rolling and speed for worn tyres.

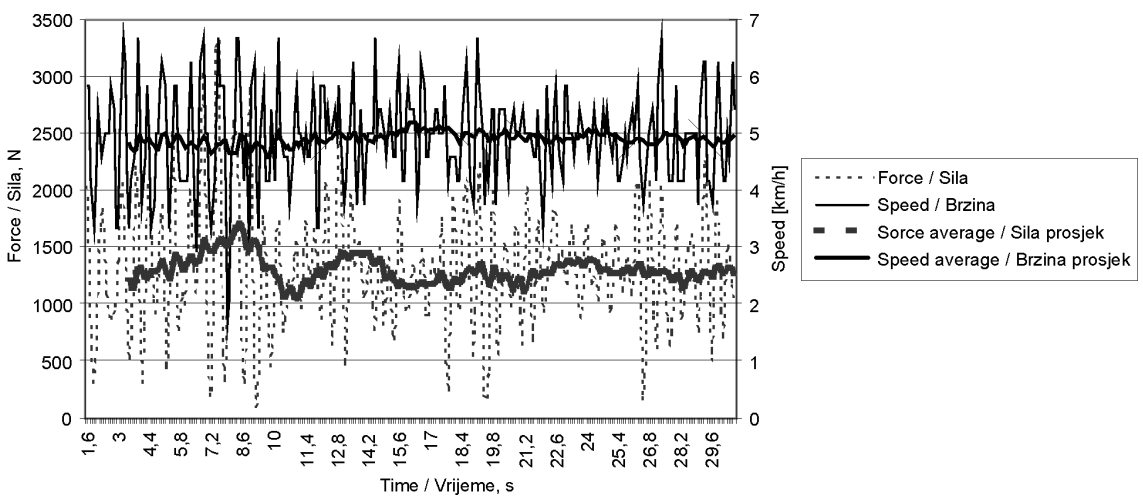

Figure 4. Resistance to rolling and speed for worn tyres

Slika 4. Otpor vožnji i brzina kod trošnih pneumatika

Figure 5 shows the resistance to rolling and speed for new tyres.

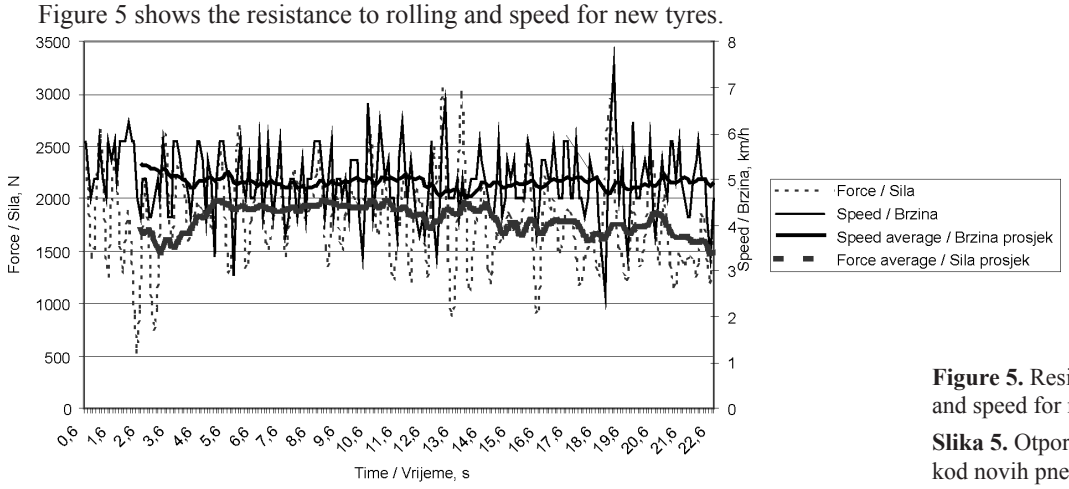

Figure 5. Resistance to rolling and speed for new tyres

Slika 5. Otpor vožnji i brzina kod novih pneumatika

Histograms in figures 6 and 7 show the frequency of distribution of data on slip and force.

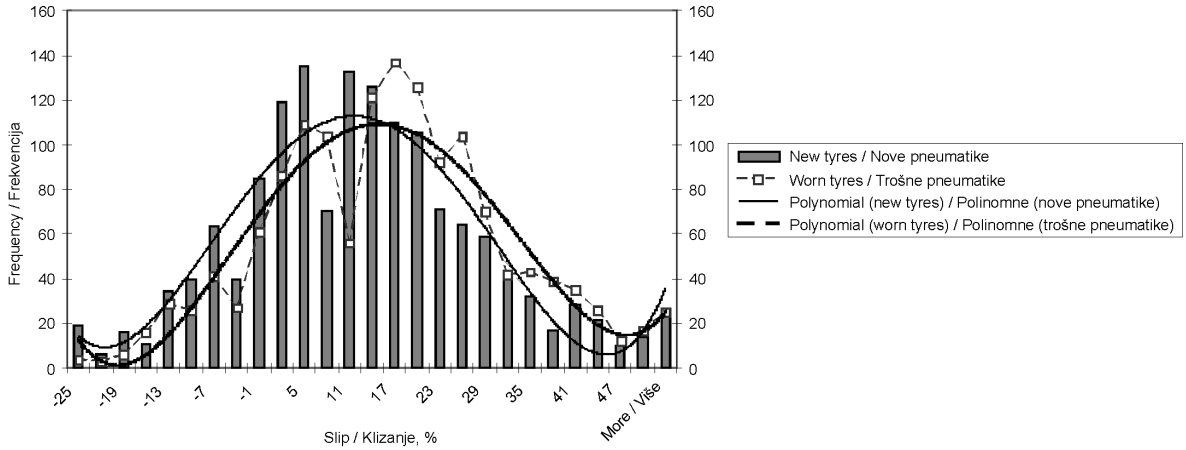

Figure 6. Histogram of distribution of data when measuring the slip

Slika 6. Histogram razdjele podataka pri mjerenju proklizavanja

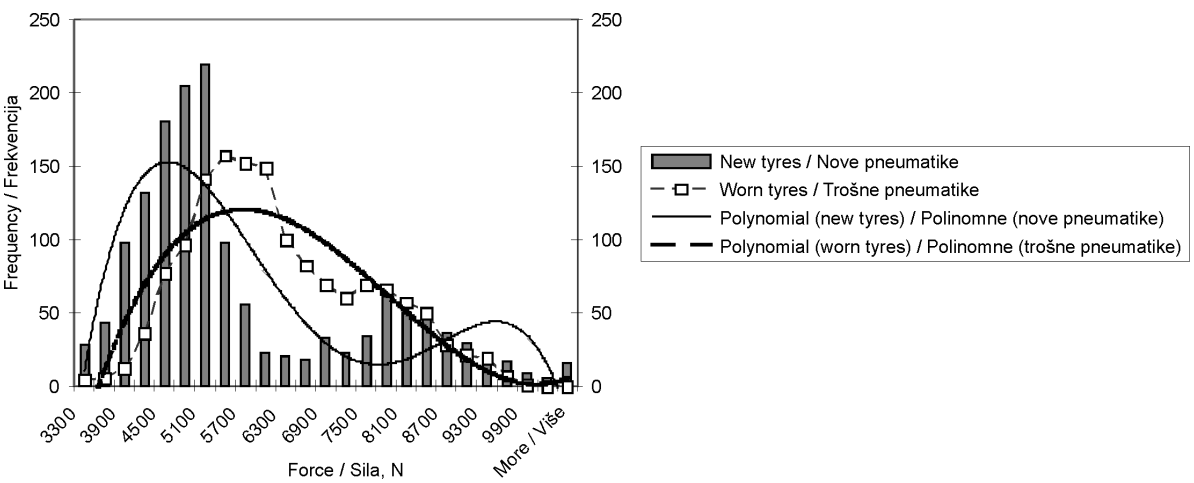

Figure 7. Histogram of distribution of data when measuring the force

Slika 7. Histogram razdjele podataka pri mjerenju sile

5. Analysis of results

When plowing the stubble field the soil humidity was 18.6 %, the cohesion 2.73 N/mm^2 and the angle of internal friction was 42 °. During most measurements the tangential force of about 5000 N with 10 – 12 % slip was developed.

When the tangential force increased to 7000 – 8000 N the slip increased to 18 – 20 %. When using both types of tyres the results were very similar. When the tangential force is above 8000 N the slip increases fast (with 10000 N the slip amounts to 40 %).

When using new tyres the force and slip curves increase much more uniformly, whereas with the increase of the tangential force the slip increases faster when using worn tyres [9].

In the graph, indicating all the data on the tangential force and slip, the slip in the range between 4000 and 8000 N is smaller for 3 – 5 % on average when using new tyres. In case the tangential force is higher than 8000 N the two slip curves begin to rise fast.

On each wheel in case of lower forces (1st and 3rd repetition) on the front axle the tangential force was higher due to the distribution of the mass among the tractor front and rear axle (70/30). In case of higher tangential force because of greater dynamic loading of the rear axle also the tangential force was equal or even greater than on the front axle (worn tyres).

On the right-hand wheel which was in the furrow a greater tangential force was found, but that difference was somewhat smaller when using worn tyres. However, this applies only for the front axle, whereas on the rear axle due to pulling of the plow and related dynamic forces the tangential force in all repetitions was greater on the left-hand wheel when using both the new or worn tyres.

In case of smaller total tangential force (1st and 3rd repetition) on the front axle the slip was considerably smaller when using either of the tyres. Only in case of greater tangential force when the distribution of the tangential force among the front and rear axle is approximately identical, also the difference between the slips on the front and rear axle is small [10].

On the stubble field the resistance to rolling when using new tyres is on average greater for 38 % than when using worn tyres. The coefficient of the resistance to rolling η_f amounted to 0.134 when using new tyres and to 0.097 when using worn tyres. The average difference was 497 N.

On the grassland the average coefficients of resistance to rolling are between 0.048 and 0.06. There is a statistical difference between new and worn tyres at 5.5 km/h speed, when in case of using worn tyres the resistance to rolling is somewhat greater.

When the tractor is loaded (controlled braking on grassland), the resistance to rolling decreases and is the smallest a little before the 100 % slip; when the slip decreases the resistance to rolling increases fast to twice times the value of the resistance in case of non-loaded tractor.

On the grassland the humidity was 15.4 %, the cohesion 4.73 N/cm^2 and the angle of internal friction was 37.2°.

When measuring the forces during controlled braking of tractor on the grassland, the maximum tangential forces in case of using either of the tyres were rather similar; the difference was not statistically significant. This is due to the fact that because of low humidity there was no sinking of the tyre ribs. In addition, also the worn tyres still had good elasticity.

A difference in the slip curve occurred. In case of 35 – 40 % slip it steeply rises to 100 %. In case of using worn tyres the curve uniformly rises to about 20 % of the slip, where afterwards it rises steeply.

When measuring on the asphalt in both cases discussed the maximum force was greater in case of using either of the tyre types: at 2.5 km/h for 9.58 % and at 6.6 km/h for 6.06 %. That difference was also statistically significant and expected because of slightly greater contact surface of the ground tyres and since in fact new tyres were ground off, they were still always elastic. The average coefficient of the pulling force amounted to 0.82 at 2.5 km/h and to 0.87 at 6.6 km/h when using new tyres. In case of using worn tyres it amounted to 0.90 at 2.5 km/h and to 0.92 at 6.6 km/h.

6. Conclusion

The literature states that in case of a 50 % rib wear the pulling force is still almost such as on new ribs. The tyres should be replaced when wear reaches 65 % and for when there are still 35 % of ribs. With the increase of the wheel slip the resistance to rolling increases due to greater tyre deformation and greater wheel sinking. The pulling force increases with the slip and, theoretically, the greatest pulling force occurs in case of 100 % slip. In practice, the greatest tractor pulling force is reached when the slip is 30 – 40 % and on wet ground when the slip is 50 – 60 %.

When driving on soft ground the resistance to rolling increases due to sinking of the wheel and formation of ruts. When driving on hard ground (asphalt, concrete) the narrower tyres with higher filling pressure have smaller resistance to rolling. On soft ground the case is opposite. Wider tyres with smaller pressure have smaller resistance to rolling due to smaller sinking. Further, on a very plastic soil the wheels of greater diameter have smaller resistance to rolling.

However, that influence is approximately smaller by half than the influence of the wheel diameter. The loose sandy ground has the greatest resistance to rolling, whereas the beaten and heavy soil has the smallest resistance to rolling. Furthermore, the soil humidity, the rib shape and size affect the resistance.

During transmission of the circumferential force from the wheel to ground also always occurs the wheel slip. It means that the wheel covers a smaller path than expected considering the wheel size. The tyre wear depends on loading, the ground type, the rubber hardness and the manner of driving. It is desirably that the tyres should wear out uniformly on the entire surface.

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